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WESTERN AUSTRALIAN GEOLOGY.

Presidential Address to the Royal Society of Western Australia.

By

A. Gibb Maitland, F.G.S.

(Delivered on the 11th July, 1916.)

"The greatest and noblest pleasure which men can have in this world is to discover new truths, and the next following this is to shake off old prejudices."

Usage prescribes that the work of the Royal Society shall be brought to a close by an address from the Presidental Chair, though the choice of a fitting subject is oftimes a source of considerable anxiety to its occupant.

In this year 1916, it is almost impossible to forget, that European nations have for well nigh two years past, been utilising the combined resources of science for the purpose of carrying on the most gigantic struggle of which there is any historical record. This fact suggests that the present and future relationships between war and science, i.e., its present use as "aids to the "lightening the burdens of humanity by the mastery of natural" "forces—the transformation of inanimate power to relieve mankind" "from arduous work, the conquest of pain and disease, and by no" "means least the enlargement of the human mind," as a fitting subject with which to conclude my allotted term as your presiding officer.

As a geologist, I however, may, along with the astronomer, lay some claim to that privilege of "belonging to a branch of science which has nothing to do with War," unless indeed those violent tremors in the region of the Mediterranean, ascribed by ancient mythology to the quiverings of that hundred armed giant, Typheus, while endeavouring to escape from his fiery prison, are indicative of internal warfare in what Hamlet calls "this goodly frame the earth," may be held to disprove the claim.

After some deliberation I have chosen to address you on a subject of my own particular science, rather than to wander as a comparative stranger into other fields.

Coming therefore to the subject of my address, I purpose departing somewhat from established custom and instead of looking backwards, will endeavour to look into the future, and point out some problems of Western Australian geology which provide abundant opportunities for collective and individual research.

Fig. 1.
Scarplike face of Darling Range.

The southern half of Western Australia affords perhaps no more striking feature than the scarp-like face of what is generally known as the Darling Range, and which forms the western rim of the Plateau of the Interior. (Fig. 1). This rim of crystalline rocks rises to heights about 1,000 feet above the broad, comparatively flat expanse known as the Coastal Plain.

The boundary between this Plateau and the Coastal Plain is virtually constituted by a nearly straight or at least a gently curving line, and forms part of a long zone in which faulting is the most important structural feature. What may be called offset faults.

may in some cases, be held to explain the want of continuity in the scarp-like face of the plateau. (Fig. 2).

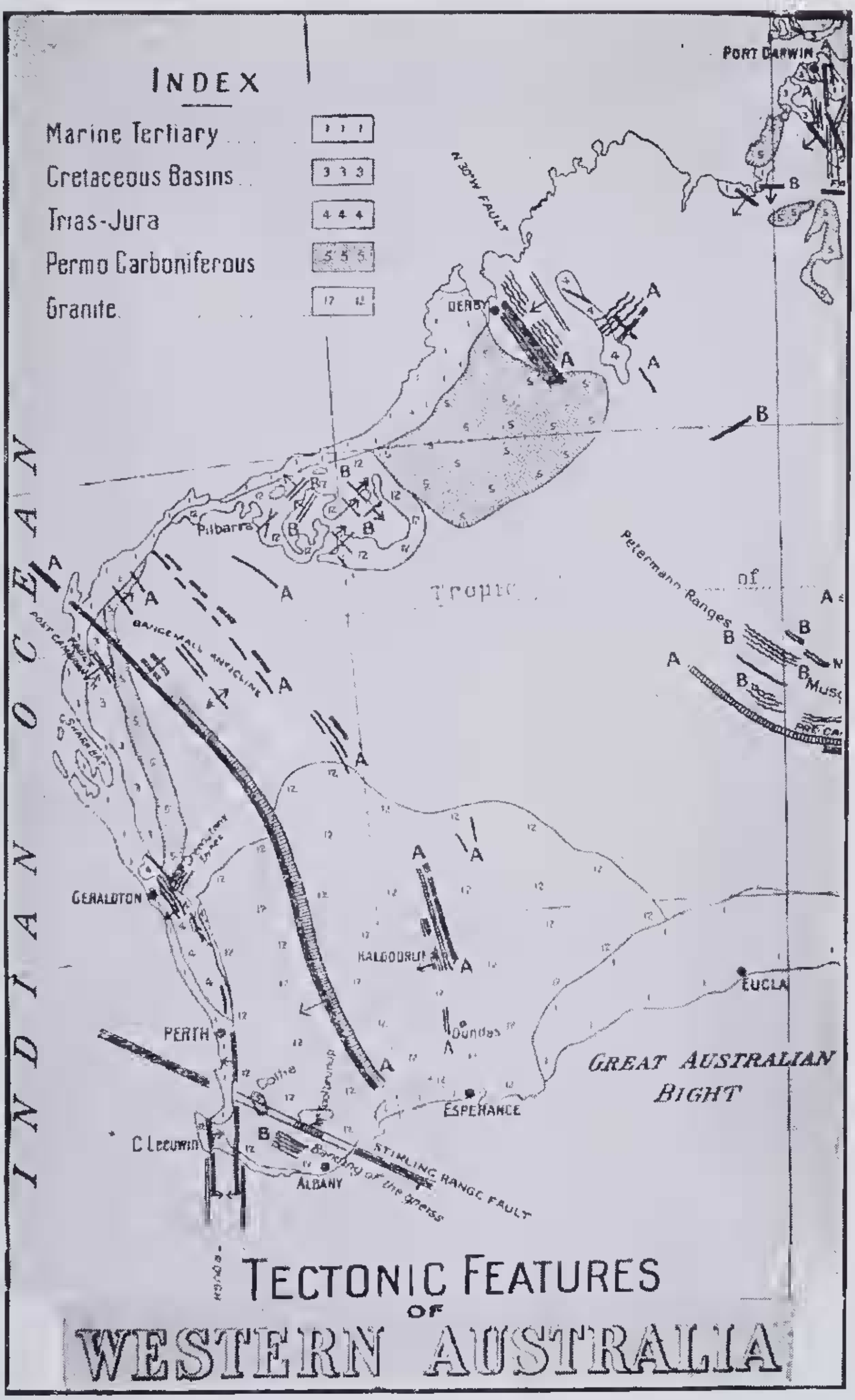

Fig. 2.

Map showing the Tectonic Features of Western Australia.

When viewed *en bloc,* this plateau presents a fairly even surface, which rises to no very great elevation above sea-level (Fig. 3); it has a very restricted and limited rainfall, and is drained by

Fig. 3.
Lake Way, East Murchison Goldfield.

Fig. 4.
Brockman Creek and Lake Carnegie.

intermittent water-courses (Fig. 4), which debouch into shallow basins, generally known as "Salt" or "Dry Lakes." (Fig. 5).

Wind erosion is the predominating denuding agent which tends to keep the plateau level. In many places the rocks have been scored by the sand-blast action. The potency of wind-scour or sand-blast may be noticed in the frosting of those heaps of discarded bottles, which in certain districts, are pretty well the sole relics of departed greatness.

Fig. 5.
Lake Dundas, Norseman. Dundas Goldfield.

It is my purpose therefore to deal briefly with some of the problems which the rocks of the old plateau present, the solution of which offers a peculiarly interesting subject for enquiry. It is not however, intended to deal with the more recent and fascinating branch of geology which concerns itself with the origin, structure, and formation of the surface features of the State.

The rocks of which the plateau is made up present a bewildering variety of lithological types, which bid fair to make this portion of Western Australia a classic field for petrological research. Portions of the plateau have been examined during very many hasty traverses, which individually yield somewhat limited information, although collectively give a good general idea of the geological structure. The rocks of the plateau have been most closely investigated in those districts in which the probability of economic development has necessitated detailed geological surveys. These localities are very widely separated, and it is now becoming imperatively necessary to link up these districts by a study of the intervening areas, though many portions being masked by residual and other deposits, the geological structure of these areas will, it is to be feared, in the absence of systematic boring, carried out under scientific guidance or extensive underground mining operations, remain more or less the subject of speculation and inference.

The oldest known rocks of Western Australia comprise a great group which almost everywhere constitute the foundation of the State; to the whole of these rocks however, observers have invariably assigned an Archaean age, but this is rather inferred than proved.

I propose to retain the term Archaean for that great basement complex of schists, gneisses and allied rocks, but although this is done, it is not meant to imply that the rocks so designated in the Northern Hemisphere and elsewhere are exactly contemporaneous.

As may be seen by a glance at the geological sketch map (Fig. 6), the great bulk of the interior plateau is granite and gneiss, the remainder being formed of the metamorphic rocks, the whole forming th foundation upon which the Palaeozoic and more recent super-structure has been built.

Fig. 6.

In the absence of any other evidence, it has been found convenient to separate these rocks into two great lithological groups, viz., (a) the gneissic and granitoid rocks, and (b) the crystalline schists.

The crystalline schists of which there are at least two distinct groups, which there is some reason to believe differ considerably in geological age; these are (1) phyllites, quartzites, conglomerates and arkoses, which have been designated the Mosquito Creek Series, and (2) an older, mica-quartz schist and marble group, associated with basic rocks which have been at times converted into greenstone schists. These rocks have been more or less irregularly folded and compressed concertina-fashion, along highly inclined axial planes; the folding is meridional, the prevalent strike being generally north-west and south-east. The broad geological structure of the western half of the State across some of these bands is shown in the section (Fig. 7), and will serve perhaps to make this clear. The dotted lines indicate the former extension of the strata. Some however, of the hornbendic rocks associated with these rocks may possibly represent original gritty beds made up of epidote and chlorite. In some instances quartzites in which original argillaceous impurities have re-crystallised as felspar and mica, render them easily mistaken for granite and its allies.

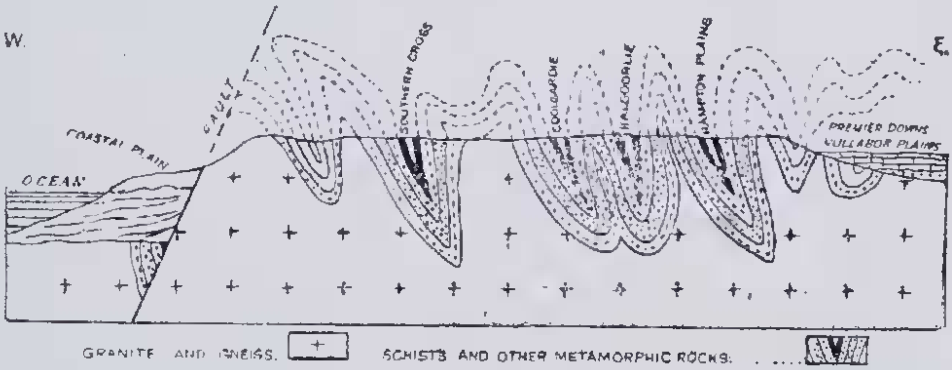

Fig. 7.
Generalised section across Western Australia from the Coast to Premier Downs.

A most noticeable feature in these crystalline schists is constituted by these bands of cherts and brilliantly coloured jasper (which often contain oxide of iron to such an extent as to warrant their being classed as iron ores). These extend as roughly parallel bands, which owing to their serrated ridges stand out in bold relief (Fig. 8), and are very much in evidence in certain districts. These bands do not always occur in straight lines, but as they have also been subject to earth movement since their formation, they are often thrown into a series of gentle curves, which vary locally in general direction.

Fig. 8.
Banded Chert, Mt. Hunt, East Coolgardie Goldfield.

One very great and important problem in connection with our Pre-Cambrian or Archaean Rocks is their division into series which may be correlated from district to district, and during the working out of the stratigraphical relationship of these, the problem is not really so hopeless as it may at first sight appear.

It is only by the application of stratigraphical methods (using this term in the widest scientific sense) to these ancient crystalline schists, that a classification quite as satisfactory as that of the rocks much higher on the geological column, can be arrived at.

These crystalline schists have been invaded by huge masses and veins of granite, which occupy some hundreds of square miles in parts of the State. The intrusion of the granite is perhaps, from the economic point of view, the most important geological event at this perod, in as much as most of the gold deposits, which places Western Australia in the front rank of mining countries in the British Empire, bear some genetic relation thereto.

The mining centre of Tambourah (Fig. 9) in the Pilbara Goldfield is one in which the intrusive nature of the granite may be readily studied, here the country is very nearly destitute of soil, and the rocks lie ready for inspection anywhere. At this locality the granite may be seen to have wandered through the schists, in addition to having engulphed and floated off extensive masses along its margin.

These granite rocks constitute composite batholiths occupying hundreds of square miles, and there seem some geological reasons for believing them to have digested and replaced very large masses of sediments. When considered in the light of their metamorphic

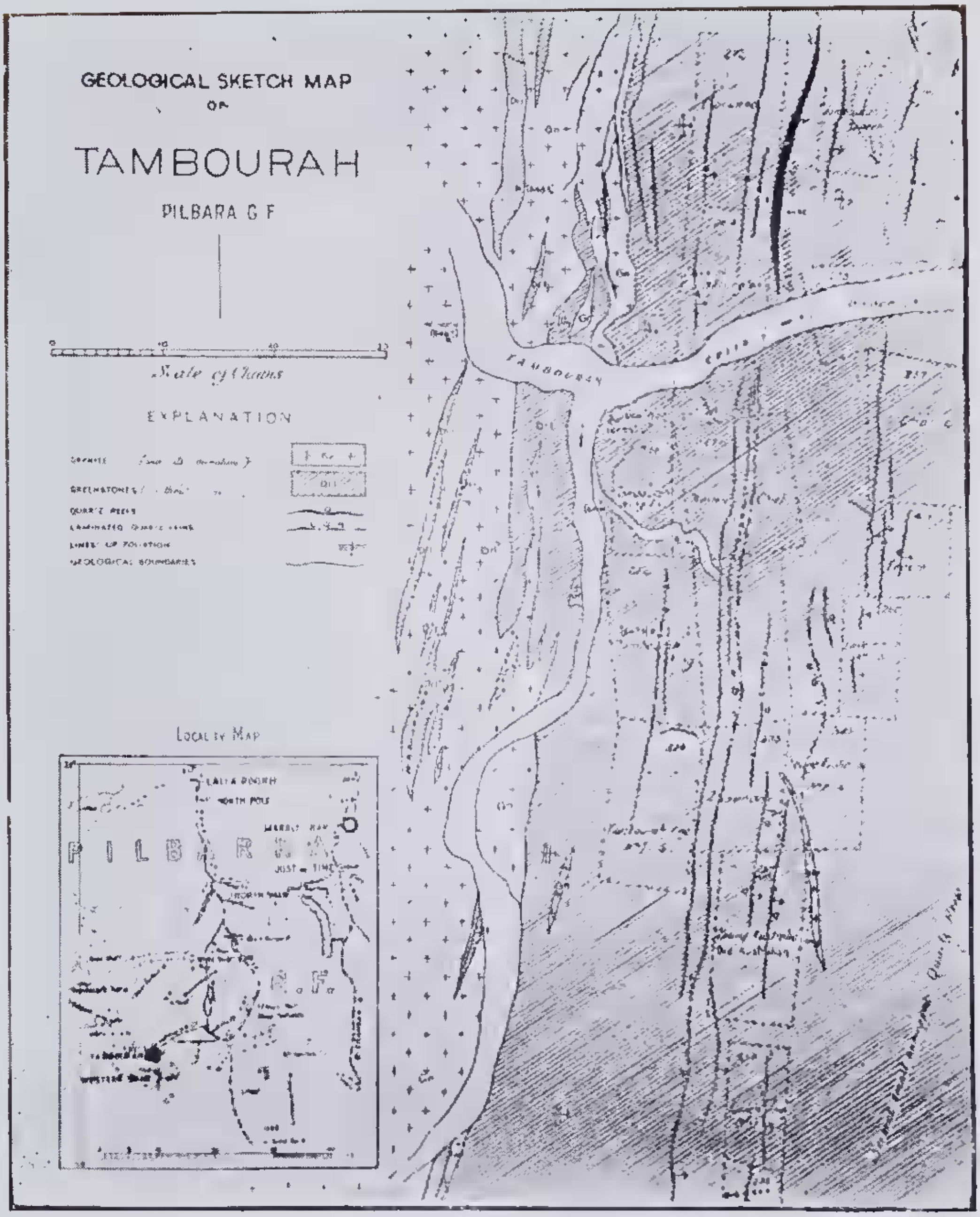

Fig. 9.

effects, these great intrusive granite masses, constitute a great significant and outstanding feature of the Western Australian goldfields geology.

Owing to the physiographic features of the Central Plateau, erosion has not yet penetrated to any depth, hence it cannot be said that the anatomy of these masses has yet been thoroughly understood.

These granites are traversed by many large ice-like quartz reefs (Fig. 10) which can be traced across country for miles; the mode of occurrence, etc., of these large quartz masses point to their being of igneous origin, representing the final product of the differentiation of a granite magma—its ultra-acid portion.

Fig. 10.
Quartz Reef, Erlstoun, Mt. Margaret Goldfield.

A great deal has been written during the last decade or two on the matter of ore deposits, mostly however, on more or less isolated occurrences, which detract very considerably from the value they would otherwise have had, and many of the later day theories on ore deposition have been based not so much upon the results of careful observation, as upon speculation, which has resulted in one eminent scientist giving utterance to the dictum that "Mining prophesies are proverbially erroneous." Very few mines present data sufficient to enable a true mental picture of the real nature of an ore deposit to be obtained, such can, however, only be arrived at by careful investigation into the geological structure and stratigraphy of wide stretches of country, where all the ore deposits are perhaps genetically connected and capable of throwing light one upon another.

Since the days of Daubree work in experimental geology has fallen somewhat into desuetude. A wide and almost untrodden field (in Australia at any rate) is open for laboratory research and experimental work, in connection with the genesis of minerals and the rock types of which they form an integral part. Work of this kind, owing to the light which the results when properly interpreted, would tend to throw on the peculiarities of the distribution of metalliferous ores, etc., can readily be seen to be of considerable economic importance. The recent experimental work upon silicate mixtures, carried out in the geophysical laboratory at Washington may be cited as evidence of the value of such investigations in connection with the two most important problems with which the geologist has to deal, viz., (a) the differentiation of silicate magmas into various rock types, and (b) the nature and order in which minerals crystallise when the molten magma has congealed into solid rock.

THE NULLAGINE FORMATION.

Resting with a violent unconformity upon these older rocks, which so far as may be judged, formed a broad continental mass, or at any rate, a group of more or less closely related islands or archipelago, is a great thickness of sedimentary rocks, which has been designated the Nullagine Formation.

This formation is made up in very large part of material derived from the denudation of the earlier continental land surface. It is impossible in the present condition of our knowledge to determine the exact amount of erosion to which this land surface has been subject prior to Nullagine time. This must have been enormous and the debris from it doubtless formed that great thickness of sediments, ranging from the Cambrian to the most Recent, which go to make up the beds forming the relatively narrow belt in the maritime districts of the State.

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The Nullagine Formation is perhaps the most widely spread of any of the rock systems exposed in Western Australia, and in some respects one of the most important. The formation has been followed from the Oakover River, across the upper reaches of the Nullagine, the Coongan and the Shaw Rivers, and from thence without a break to Roebourne and southwards to the Fortescue River. The same series of constitutes the Hamersley Range, which contains Mount Bruce, one of, if not actually the highest summit of the State, it also makes up that rough tableland which divides the waters of the Lyons from those of the Ashburton River. The southernmost boundary of this large exposure is in the neighbourhood of Mount Russel, in south latitude 26deg. 30lat., not far to the south of Lake Way. In its lithological characters, its behaviour and general aspect, the Nullagine Formation bears a very striking resemblance to those beds which constitute one continuous series in that tableland, which extends from Wyndham to Mount Hart, a prominent summit near the southern face of the King Leopold Plateau, in the Kimberley Division.

The Nullagine Formation makes a very prominent feature in the landscape in those regions in which it is developed, presenting as it does a plateau-like appearance, owing to certain of the harder beds standing out in bold relief, and forming mural faces at different levels as at Mount Margaret in West Pilbara. (Fig. 11).

Lithologically the strata consist of a group of sedimentary rocks, sandstones, quartzites, conglomerates, and dolomitic limestones. Associated with these beds, igneous rocks are specially abundant, and according to their mode of origin they are readily divisible into two classes, some were formed from congealed molten

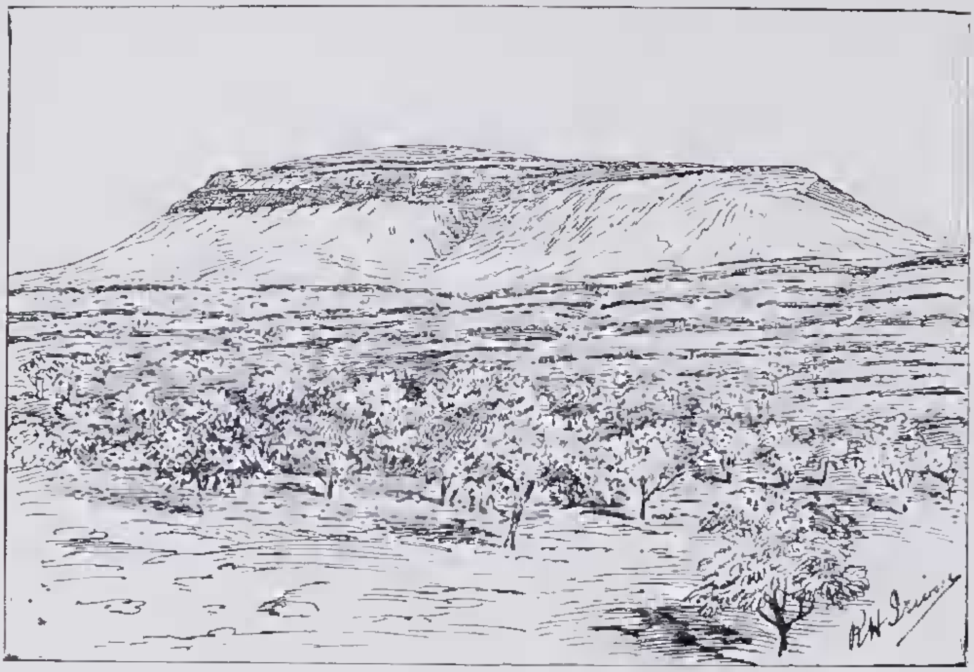

Fig. II.
Mt. Margaret, Hamersley Range, West Pilbara Goldfield.

matter, crystallising as dolerite, which forced its way either along the planes of bedding or across the strata in the form of intrusive sheets, sills or dykes. The others were contemporaneous with the deposition of the associated sedimentaries and include outpourings of lavas, ashes and other volcanic ejectmenta.

The results of field investigation extending over ten years, in the enormous area occupied by this formation and its equivalents, have shown it to be of absorbing interest to the petrographer, and the student of volcanic geology, as it was without any doubt the most active centre of eruptive energy, to be found in Western Australia during this geological epoch. The gold-bearing character of the basal members of the formation has given additional scientific interest to the series, and added considerably to its otherwise economic importance.

As our exploratory field work has proceeded, coupled with detailed mapping in certain economically important localities, the true character and significance of the Nullagine Formation has been gradually unfolded. Its systematic study opens up a field which bids fair to offer a rich harvest, and when the crop has been gathered, it will be found that valuable additions have been made to the sum total of our knowledge of the igneous rocks and phenomena of Western Australia.

In the neighbourhood of Nullagine from which the formation takes its name, the violent unconformity separating the series from the underlying beds is to be seen. The basal member of the Nullagine Formation is a massive layer of coarse conglomerate made up of rounded ellipsoidal, or sub-angular fragments of the underlying beds. The conglomerate often includes boulders which reach lengths of 4 to 5 feet, though the bands containing the large fragments are merely local. Figure 12 shows a portion of this

Fig. 12.
Auriferous Conglomerate, Grant's Hill, Nullagine. Pilbara Goldfield.

conglomerate at the entrance to one of the mine workings, reef quartz identical in character with that forming the auriferous deposits in the underlying strata, being a very common constituent. The pebbles are imbedded in a matrix, which is principally sandy, though sometimes aluminous. Limonitized pyrites up to two inches in length, often forms an important constituent of the conglomerate or consolidated shingle; owing to the climatic conditions these pseudomorphs offer very great resistance to atmospheric influences and retaining the exact form of the original pyrites, crystals accumulate in fairly large quantities on the surface.

The flats in the neighbourhood of Nullagine are covered with a heterogeneous collection of boulders and blocks, derived from the disintegration of the basal conglomerate, of which a good view may be seen in Fig. 13.

Considerable interest attaches to the nature of portions of the basal conglomerate as exposed in the vicinity of Kadgebut Spring, a watering place some miles to the south of Nullagine township, where the conglomerate is seen to contain some flattened and striated pebbles of rocks identical with those forming the underlying strata. The special interest attaching to these striated pebbles lies in the fact that a glacial origin had been assigned to them by my

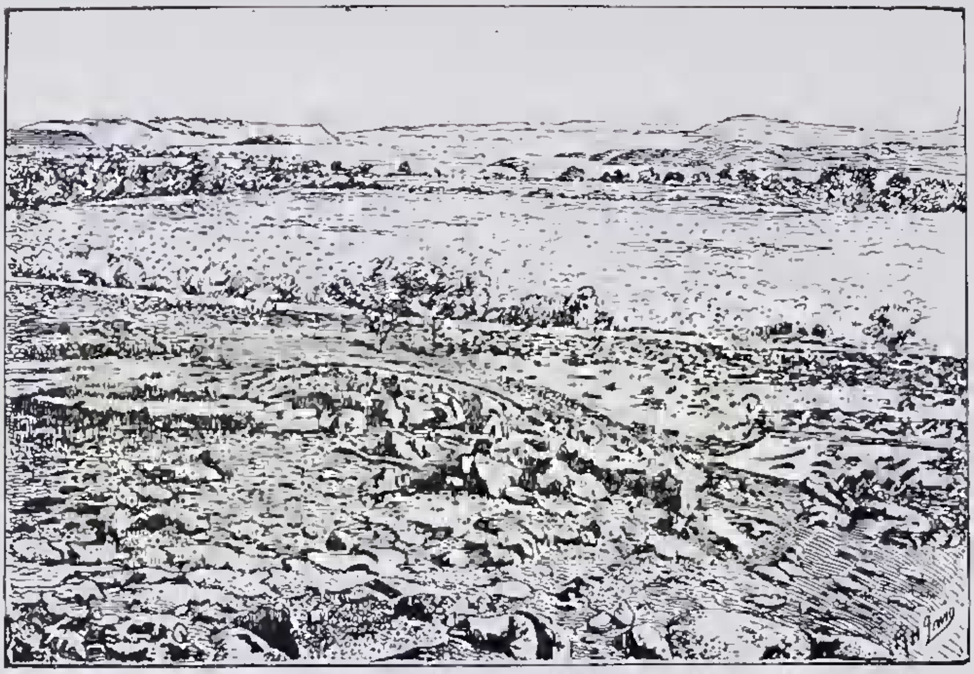

Fig. 13.
Boulder-strewn Flats, Nullagine, Pilbara Goldfield.

colleague, the late Mr. Becher, who was the first to commence the scientific study of the beds of the Nullagine Formation in the type district. Relying chiefly on the literature, a glacial origin for these was subsequently assigned by Professor David. These flattened pebbles however, I think, owe their striated character to mechanical deformation and not to ice action, a view also held by Dr. Jack, who has had considerable experience in glacial deposits, and who has also had an opportunity of examining the specimens in question.

The basal conglomerate at Nullagine is about 300 feet in thickness, though in some localities this is missing, whilst at Just-in-Time, 8 miles from Marble Bar, where it had been mined for its gold contents, the bed varied from one inch to five feet six inches in thickness.

Another good section is to be seen in the vicinity of Goonanarrina Pool on the Sherlock River where the conglomerate—a view of which is depicted in Fig 14—is seen to rest upon a platform of granitic gneiss and crystalline schists.

At Little Mount Phillips in the Barlee Tableland, the basal bed is a coarse boulder conglomerate, which is pretty well vertical.

In other localities, as at Rooney's Patch, at the head of the Oakover River (at. 23deg. S., long. 120deg. 35min. E. approx.) the basal beds of the Nullagine Formation are, as may be seen in Fig. 15, very angular, and the rock is rather a breccia than a conglomerate. This may really represent a scree or talus deposit.

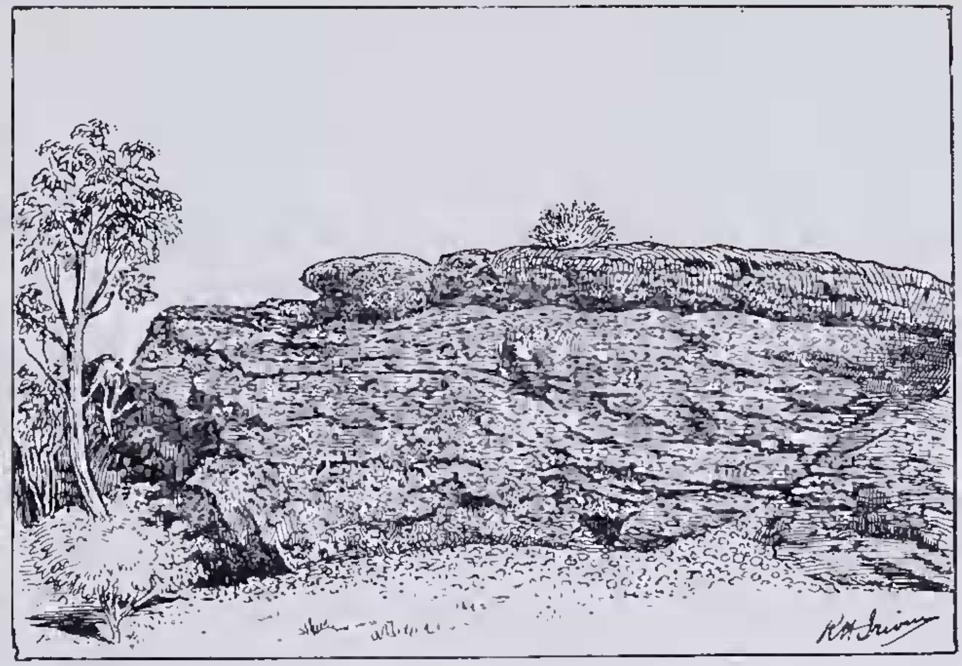

Fig. 14.

Basal Conglomerate, Nullagine Formation. Sherlock River, West Pilbara Goldfield.

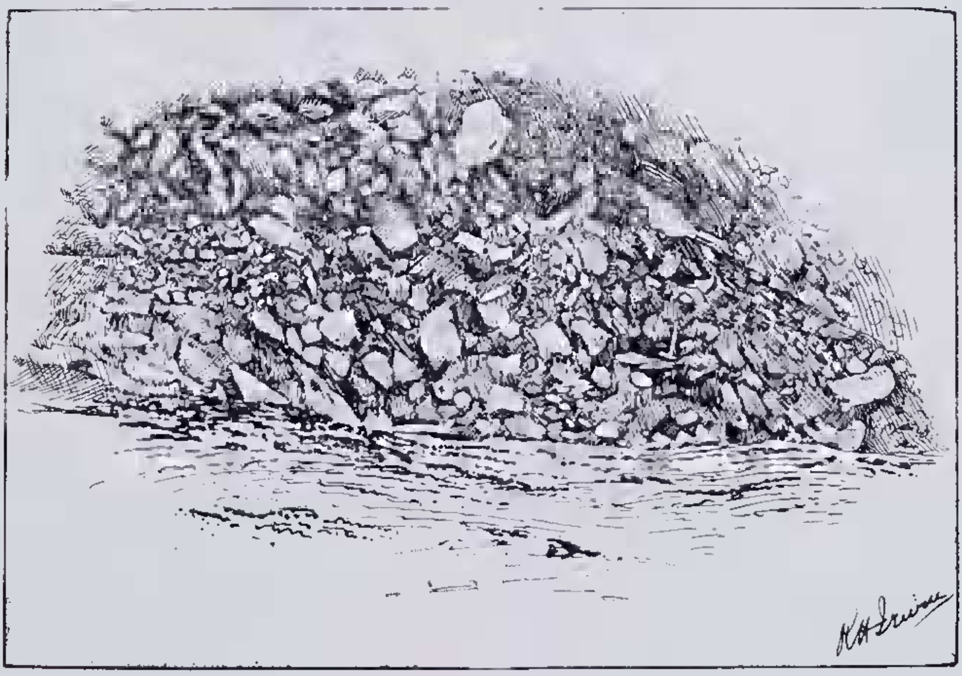

Fig. 15.

Weathered Conglomerate. Nullagine Formation. Rooney's Patch, Oakover River.

From the angularity of many of the pebbles in the conglomerate it may be reasonably inferred that the coast-line which furnished them was not far distant, and in all probability the present boundaries of the series approximately marks the original shore line.

What I believe to be an outlying patch of the Nullagine Formation occurs at Mt. Yagahong, near Meekatharra. Here the beds which are practically horizontal, rest upon a granite floor. The basal bed is a thin conglomerate made up of pebbles of granite, above which, as may be seen in the cliff sections are a series of dark fine-grained sedimentary rocks. (Fig 16). The beds of the King Leopold Plateau, wherever I have had an opportunity of examining them, everywhere exhibit a remarkably uniform sandstone facies, indicating but little change in sedimentation in this portion of the State, at this period.

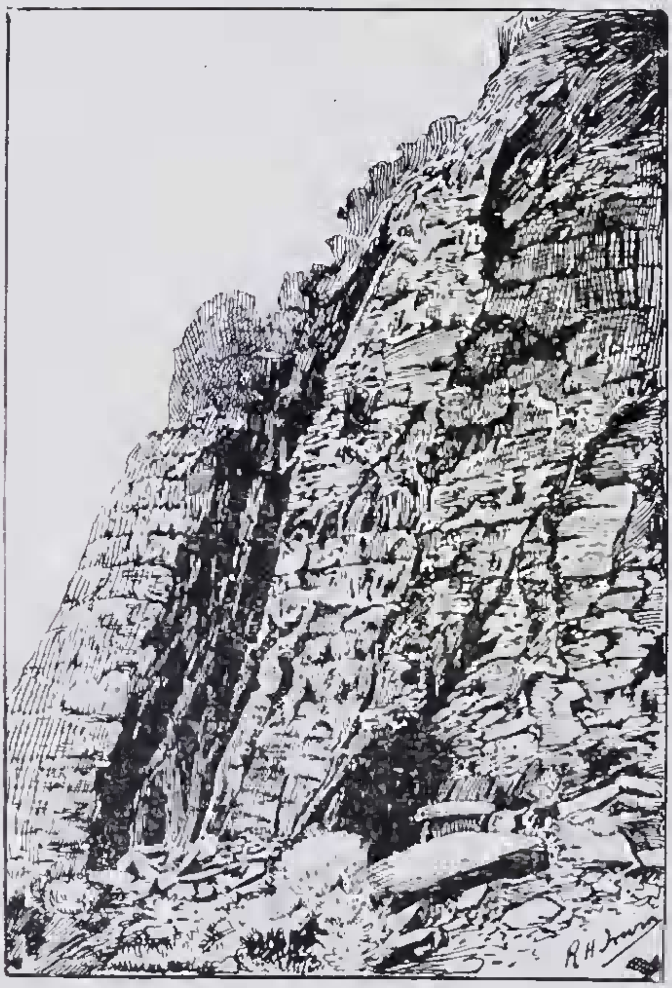

Fig. 16.
Sedimentary Beds. Mount Yagahong, Murchison Goldfield.

Before the close of the period represented by the conglomerate and boulder beds to which reference has just been made, volcanic activity commenced in that portion of Western Australia now occupied by the Nullagine Formation. From numerous and widely separated centres of eruption, of which the remains at present exist, lavas and ashes were thrown out, submerging fairly large areas of country. So far as researches in the field have been carried, the volcanic focii, all seem to be situated along or on the northern portion of the area in proximity to what would appear to be the shore line of a gradually receeding ocean. The great extent of the lava flows and associated ejectmenta seem to imply that these centres of eruption must, during Nullagine time, have appeared as a remarkable chain of coast volcanoes, but whether they are distributed along lines of orographic movement is one of those, as yet unsolved problems of Western Australian geology.

The occurrence of sandstones, quartzites and other sediments interbedded with lava flows, etc., point to the fact that some of these volcanic eruptions took place under water, and must have been followed by intervals during which sedimentation was carried on.

In the King Leopold Plateau in the far north, these volcanic beds occur in great force, and form the highest parts of the country.

At Mount Hann, a very remarkable cliff-faced mountain situated on the highest summit of the plateau, dissected by the upper reaches of the King Edward, the Drysdale and the Prince Regent Rivers, the volcanic rocks can be well seen. (Fig. 17). The

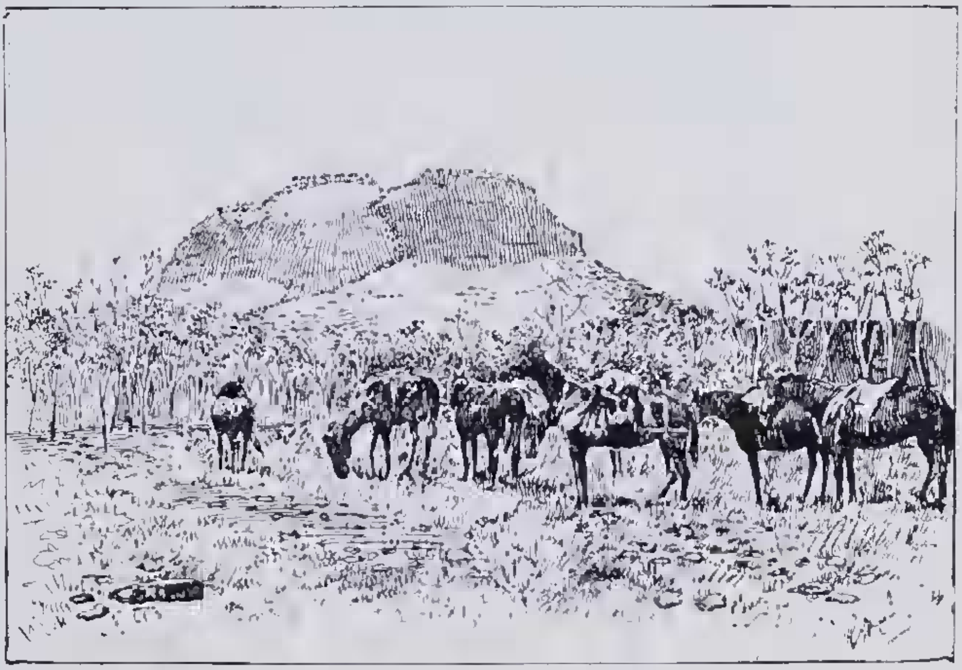

Fig. 17.
Volcanic Rocks, Mount Hann, Kimberley Division.

cliffs formed by the faces of the lavas and ashes, rise perpendicularly from 100 to 300 feet in height. Only one spot on the western face of the mountain by which an ascent could be made was found. From the summit of Mount Hann, about 300 feet in height, an excellent view of the surrounding country could be obtained, and the great extent of the volcanic rocks visible; they were seen about 5 or 6 miles west of the mountain, to rest upon quartzites, which occupied the country as far as the tidal waters of the drowned valley of the Prince Regent River.

In the vicinity of Synnot Creek in the King Leopold Plateau, is a very coarse volcanic breccia which covers a very wide area, and is associated with the lava flows; as a rule the ashy beds are

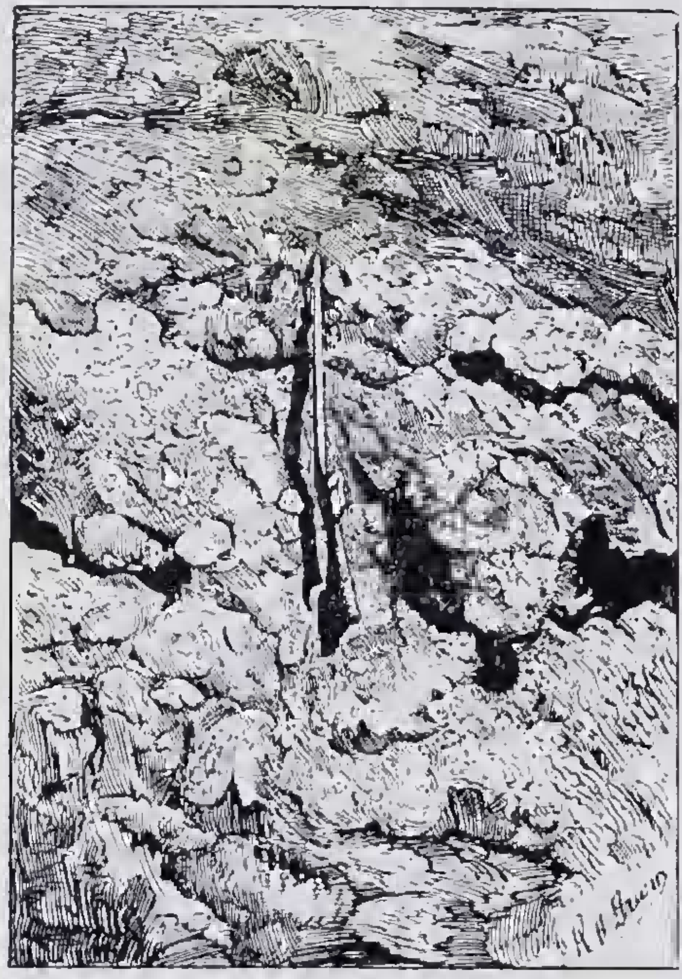

Fig. 18.
Volcanic Breccia, Synnot Creek, King Leopold Plateau, Kimberley Division.

very much finer in grain than that shown in Fig. 18. In this particular instance, it seems quite clear that the coarse agglomerate occupies the throat of one of the volcanic vents which has not yet entirely disappeared by denudation; it is still surrounded by lava flows and fine-grained ashy beds. In the heart of the Hamersley Range (or plateau) the sedimentary rocks may be seen underlying the beds of the volcanic series. (Fig. 19).

In certain localities these volcanic rocks reach a very considerable thickness, often over 500 feet.

So far as our observations have been carried, it appears that, as a rule these lavas have the composition of basalts or dolerites.

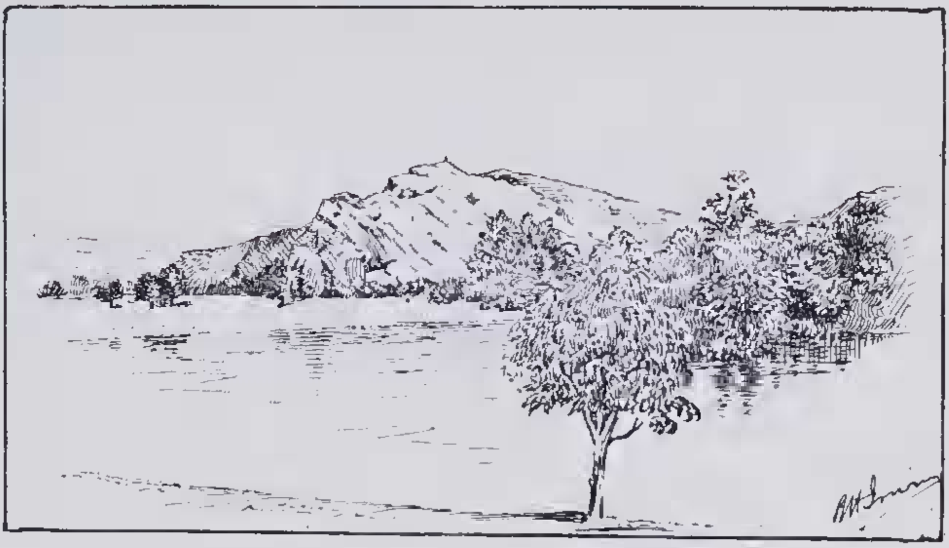

Fig. 19.
Stratified Rocks beneath the Volcanic Series, Fortescue Gorge, Hamersley Range.

though in certain places, such as Mount Ankatell they are closely allied to the augite-andesites; while at Bamboo Creek on one of the tributaries of the Coongan River, acidic lavas, quartz felsite, or rhychte, occur near the base of the Nullagine Series.

The steam-holes in many of the amygdaloidal lavas are filled with secondary minerals, partly chalcedony and partly calcite.

The wide-spread occurrence of these lavas and their associates, which are much more numerous and wide-spread in the far north, nearer to that great circle of fire which forms a festoon round Northern Australia, and the relatively few volcanic focii so far noticed, would seem to imply that fissure eruptions played an important part in the formation. This type of volcanism finds a parallel in the 200,000 square miles occupied by the Deccan Trap areas of India, and those extensive lava plains of Northern Queensland, which I have been privileged to examine.

As has already been pointed out, the Nullagine volcanic series lies very near the base of the formation, and the lavas from which it is made up vary in composition from basic to acidic. The precise cause of this differentiation, which seems to have produced what may be called a gradational series of rock types, has an important theoretical bearing, yet requires careful investigation.

An important group of carbonate rocks occupies a distinctive and well-marked stratigraphical horizon in the Nullagine Formation, and covers a very considerable area of country in the Barlee and Hamersley Ranges, and in the valleys of the Ashburton and Oakover Rivers. As developed in these districts the group normally consists of magnesian limestones, which vary somewhat not only in chemical composition but in general appearance. Several analyses of these have been made, and the limestones have been found to contain from 12 to 22 per cent. of carbonate of magnesia, from 14 to 30 per cent. of carbonate of lime and of carbon dioxide from 21 to 47 per cent., in addition to varying proportions of silica.

The limestones often have a characteristic surface not unlike an elephants hide. On account of its definite characteristics, and its mode of origin which serve to separate it from the bulk of the Nullagine beds, it has been deemed advisable to designate the group by a distinctive specific name. For this purpose I propose to adopt for this lithological and stratigraphical unit, the name, *The Carawine Dolomite Series*, from the name of that locality on the Oakover River, where the dolomite is so well developed and where the numerous beautiful cliff-sections afford splendid opportunities for investigation. (Fig. 20).

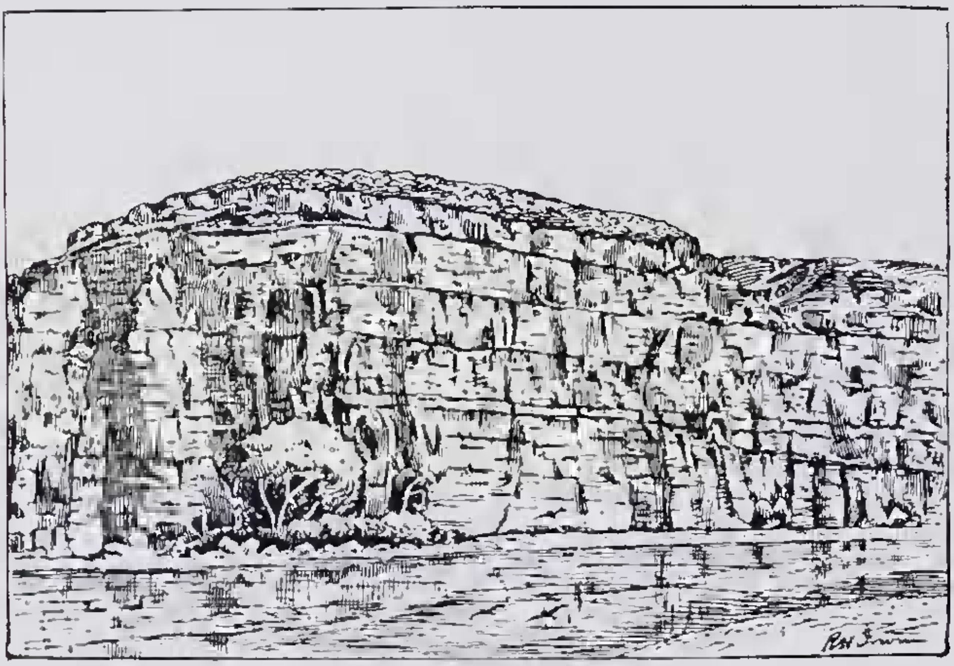

Fig. 20.
Dolomitic Limestone, Carawine Pool, Oakover River, Pilbara Goldfield.

The thickness of the limestone in the Carawine Pool* section is as measured not less than 300 feet; the base of this bed of dolomite is exposed on the eastern side of the Pool, and is seen to rest upon a volcanic rock. The limestone contains bands of chert and jasper, which have not however, up to the present yielded any recognisable fossils, though in all probability their origin may be ascribed to the accumulation of siliceous skeletons of sponges or diatoms. The limestone as exposed at Carawine covers a very wide extent of country, for it has been found to be continuous at least 20 miles to the southward. In certain localities springs of water, highly charged with carbonate of lime, issue from the cliffs

*Lands Department Litho. 108/300.

at the rate of many thousands of gallons per day. Some of the limestones at Carawine have been faulted. (Fig. 21).

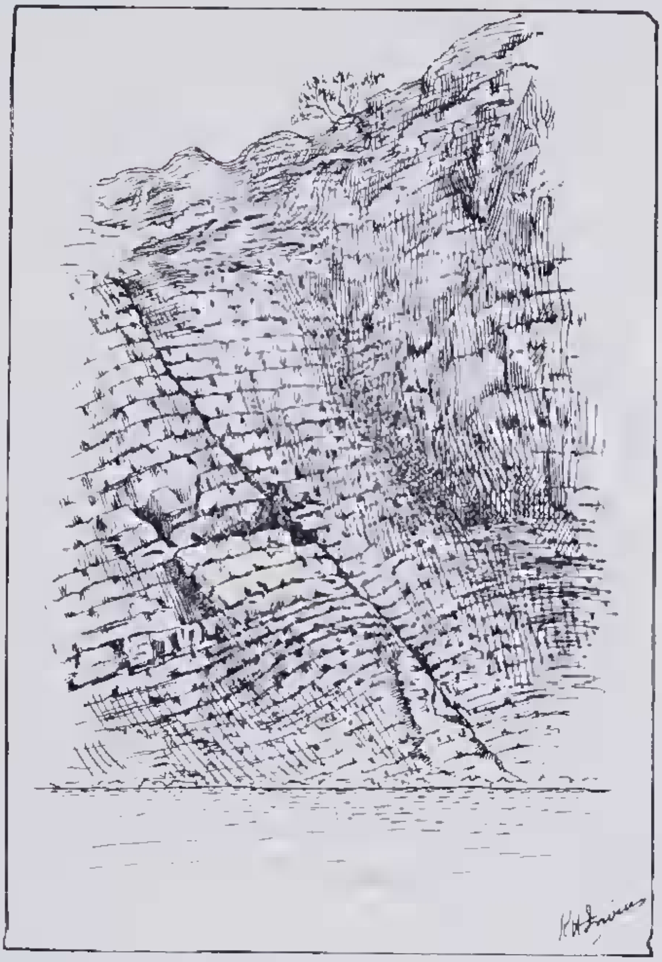

Fig. 21.
Fault in Dolomitic Limestone, near Carawine Pool, Oakover River, Pilbara Goldfield.

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At Irregully Creek, in the Ashburton River, the Carawine Dolomite Series, which in this locality consists of gently inclined flaggy limestones, rests upon a bed of conglomerate two or three feet thick, which in its turn reposes directly, and with a violent discordance on the older beds beneath. Near the mouth of Soldiers' Secret Creek, another important tributary of the Ashburton River, the limestone which is at least 350 feet thick rests directly on the upturned edges of the schists and slates, which form the matrices of the auriferous deposits. No conglomerate was found at the base of the Nullagine Formation, as developed in the tableland which forms the divide between the watershed of the Lyons and the Gascoyne.

What may possibly turn out to be the northern extension of the Carawine Dolomite Series is to be found in the Napier Range in Kimberley. (Fig. 22).

Mount Russell*, a hill on the boundary between the Murchison, Peak Hill, and East Murchison Goldfields, distant about 25 miles

* Lands Dept. Litho. 60/300.

north-west from Lake Way, and which rises to about a height of 250 feet above the general level of the surrounding country, is built up of dolomitic limestone which however, is represented by only very thin beds, nowhere exceeding three or four feet in thickness, alternating with siliceous shales or slates. (Fig. 23). The beds are almost uniformally horizontal,

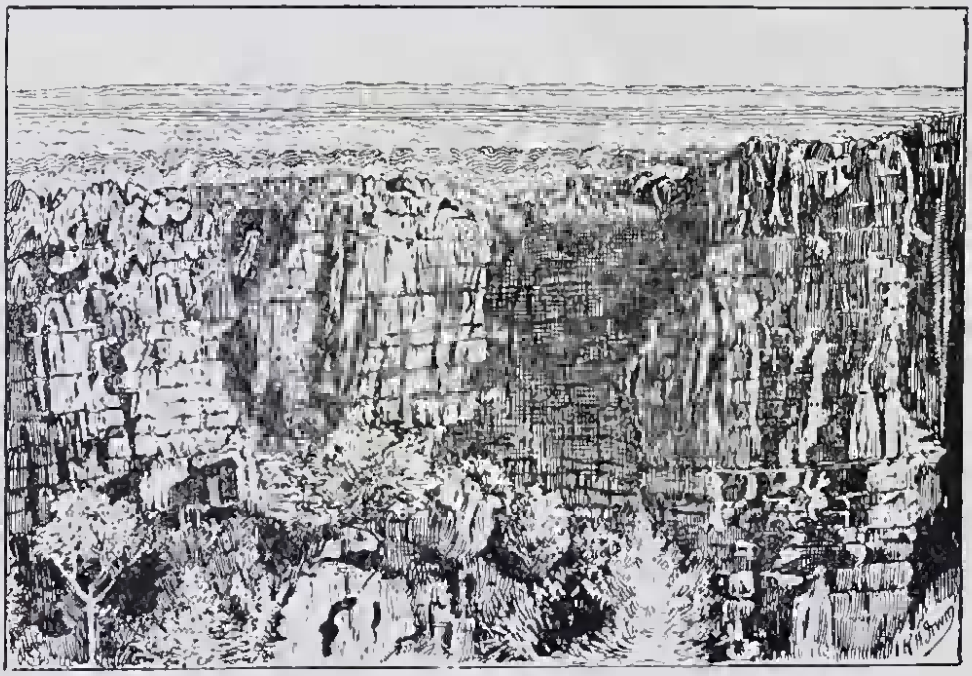

Fig. 22.
Limestone Cliffs, Napier Range, Derby, Kimberley Division.

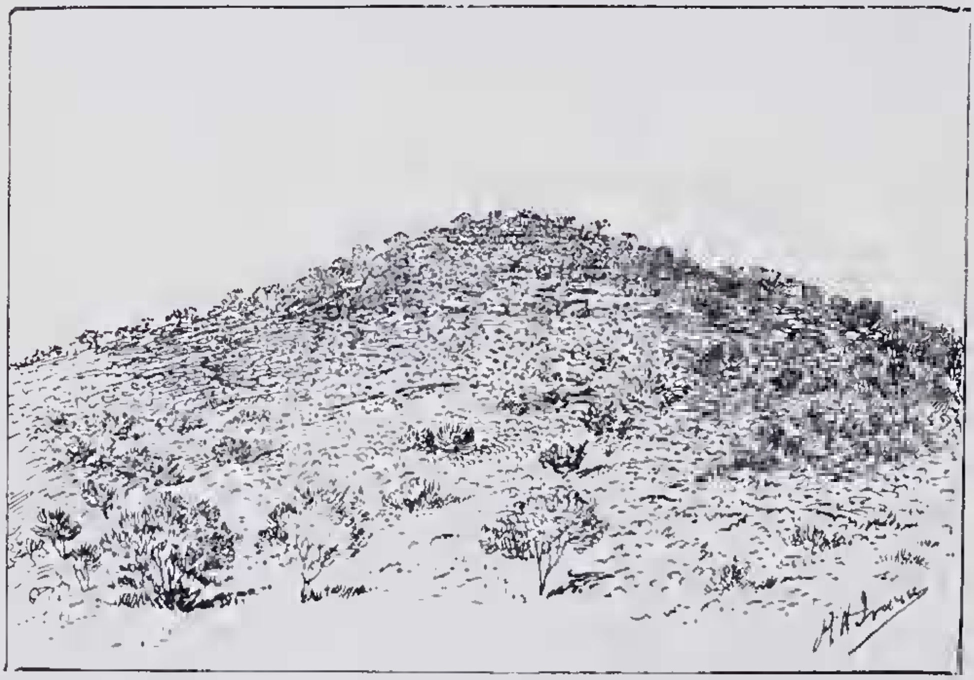

Fig 23.
Flaggy Dolomitic Limestone and Shale, Nullagine Formation, Mount Russell, East Murchison Goldfield.

and the general succession indicates a condition such as is often found in proceeding from a shore-line to deeper areas of deposition. The limestones are clearly of marine origin, and as the siliceous beds are found to alternate with them, it may be inferred that they were also laid down in the sea, of which the southern margin is defined by the beds of Mount Yahagong, in lat. 27 deg. South, to which reference has already been made. The Nullagine Sea, therefore, extended over about fourteen degrees of latitude, north of Mt. Yahagong, near Gabanintha.

Lying conformably above the Carawine Dolomite Series is a considerable thickness of arenaceous sediments, quartzites, ferruginous sandstones, grits with subordinate sandy shales. At Mount Margaret in the Hamersley Range, these are represented by very fine-grained ferruginous flaggy sandstones with some very siliceous bands, and also some banded ironstones, the beds being practically horizontal. The ferruginous beds contain magnetite and hematite, the percentage of iron being as much as from 28 to 37 per cent. These ferruginous quartzites, jaspers or cherts, are sometimes somewhat calcareous. These banded ores bear a very remarkable resemblance to those banded ores, jaspilites, etc., which make such conspicuous features in most of the southern goldfields, and suggest a common origin for the two. An excellent example of these banded jaspers is to be seen in the Coongan River at Marble Bar, which perhaps may be regarded as typical. (Fig. 24).

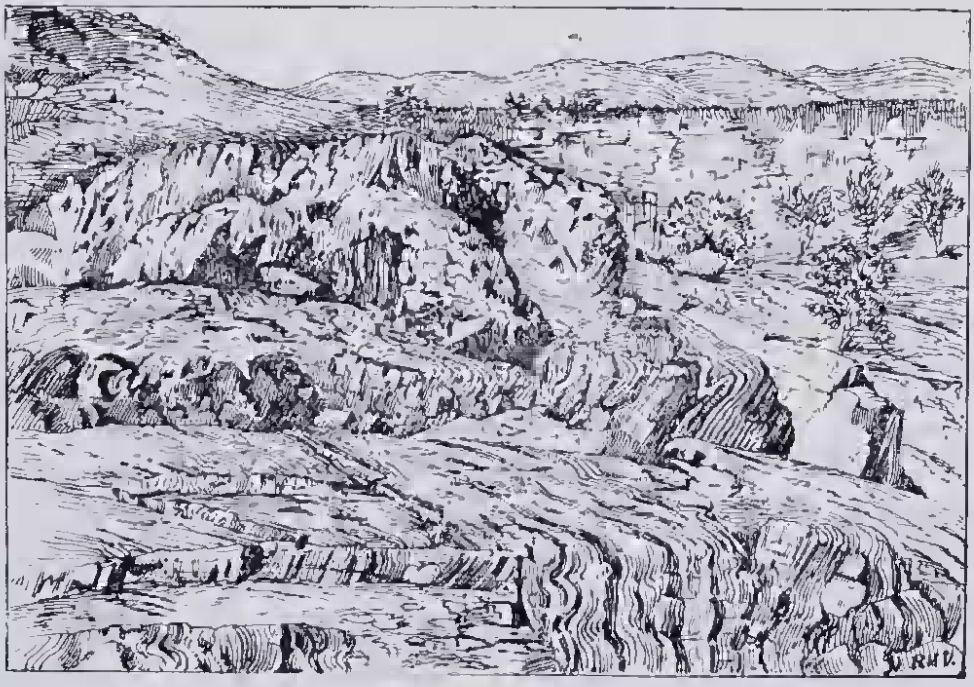

Fig. 24.
Jaspilites, The Marble Bar, Coongan River, Pilbara Goldfield.

Here the laminae forming the "Bar" dips at an angle of 50deg. to the west. The thickness of the bed is about 220 feet from wall to wall. The rock presents a brilliant appearance due to the interlamination of red, white, and dark coloured bands. The ferruginous beds of the Hamersley Range are clearly of sedimentary origin. Near Yelina Soak,* these sediments are seen to be gently folded (Fig. 25) and at Punda Spring** (Fig. 26) the ferruginous beds are very

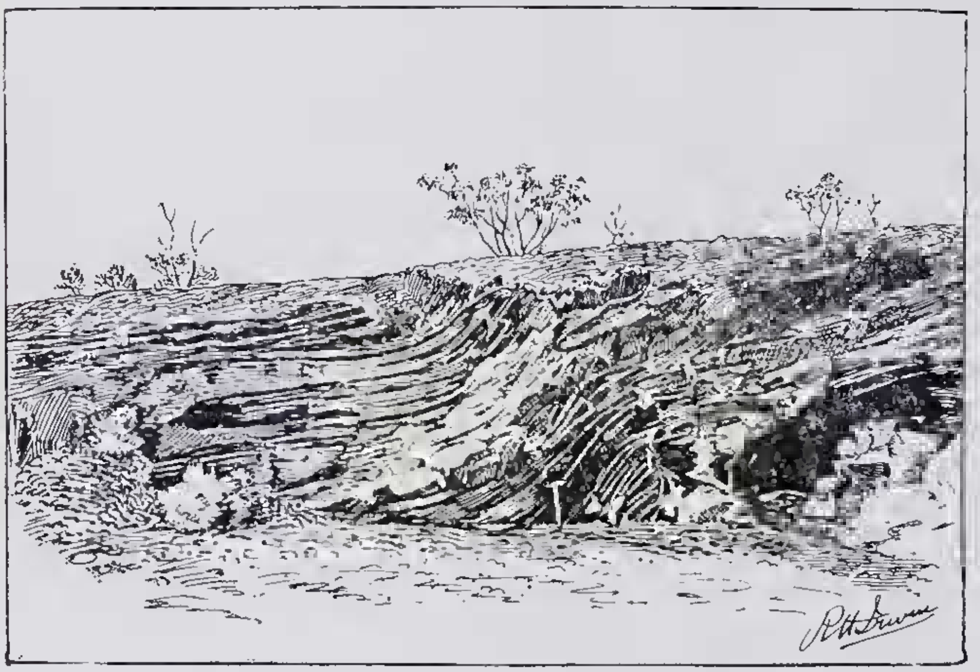

Fig. 25.
Curvatnre in Sandstone, Yelina Soak, East Murchison Goldfield.

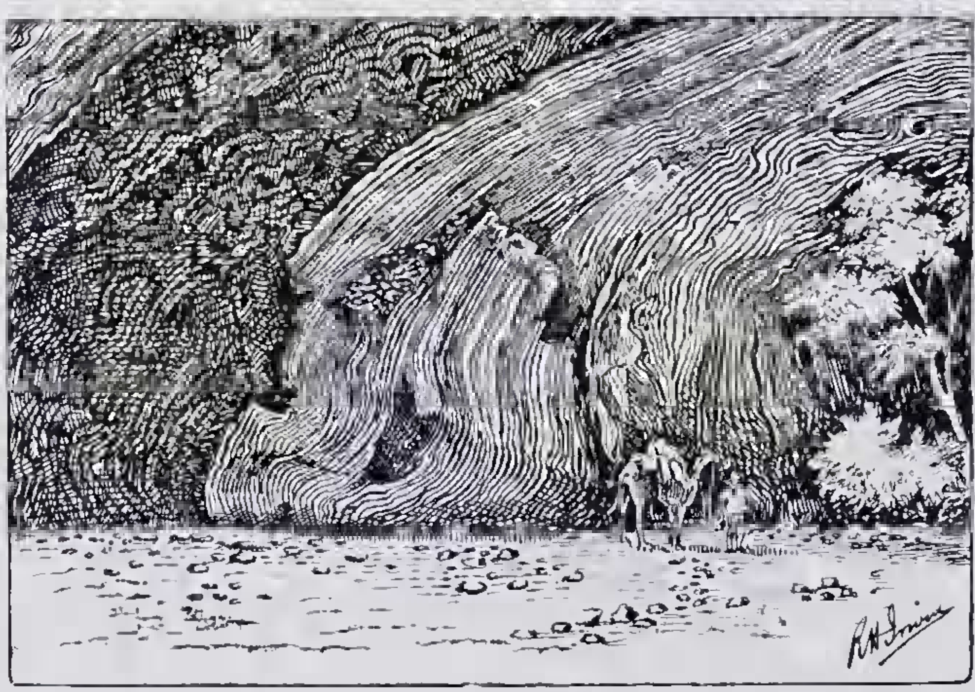

Fig. 26.
Contorted Jaspilite, Nullagine Formation, Punda Spring.

*Lands Dept. Litho. 61/300.
**Lands Dept. Litho. 91/300.

violently contorted, reminding one very forcibly of the contorted jaspilites as seen in the goldfields to the south, an excellent example of which is to be seen at Marda (Fig. 27), near Mount Jackson in the Yilgarn Goldfield.

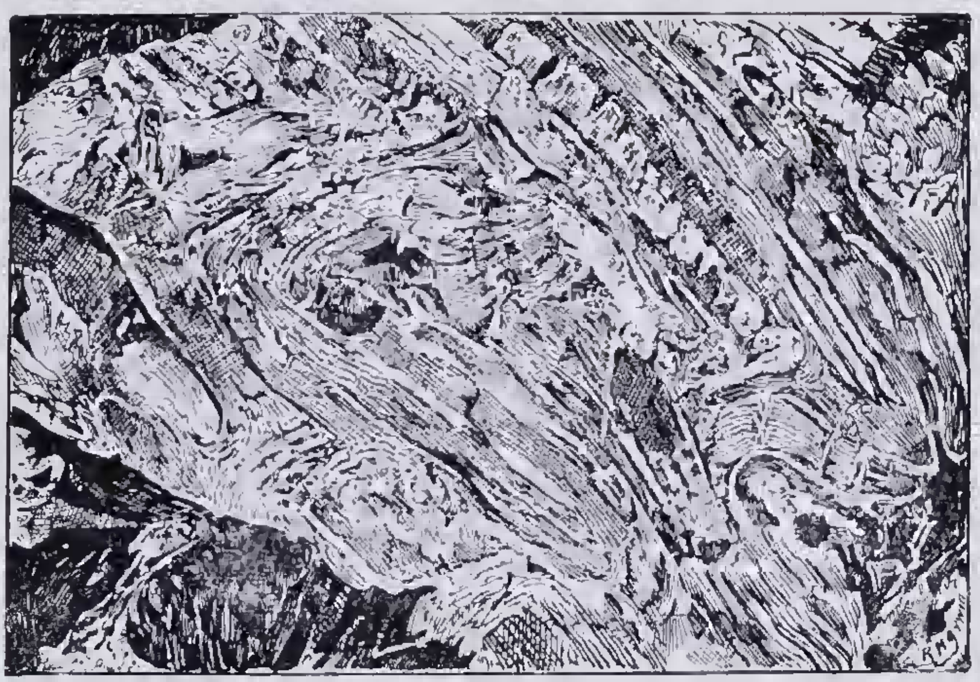

Fig. 27.

Contorted Jaspilite, Marda, Mount Jackson, Yilgarn Goldfield.

A remarkable, and very important feature in the plateau region occupied by the Nullagine Formation is the abundance of dolerite intrusions, which take the form either of nearly horizontal sills or steeply inclined dykes.

These dolerites have a remarkably uniform composition, and wherever they have been examined th rocks exhibit little or no trace of recrystallisation or other signs of metamorphism. Occasionally a glassy selvage due to rapid cooling may be noticed occuring at the contact between the dykes and the rocks it traverses. The dolerites seem to be in practically the same condition in which they originally congealed, and no great terrestrial disturbance seems, when the Nullagine Formation is viewed broadly to have effected the region since the time of their injection. The dykes are all readily distinguished by their dark-greenish colour, a rusty and in places exfoliating weathering. Some extend across country in more or less straight lines for many miles, and give rise to fairly conspicuous features standing out boldly on the back of the ridge, of which an excellent example, the Black Range (Fig. 28) is to be seen in Pilbara. The name is given from the almost black weathered rocks of which the range is made up. One of these dykes or sills may be seen near Mt. Frew* invading the sedimentary rocks along the planes of bedding. (Fig. 29).

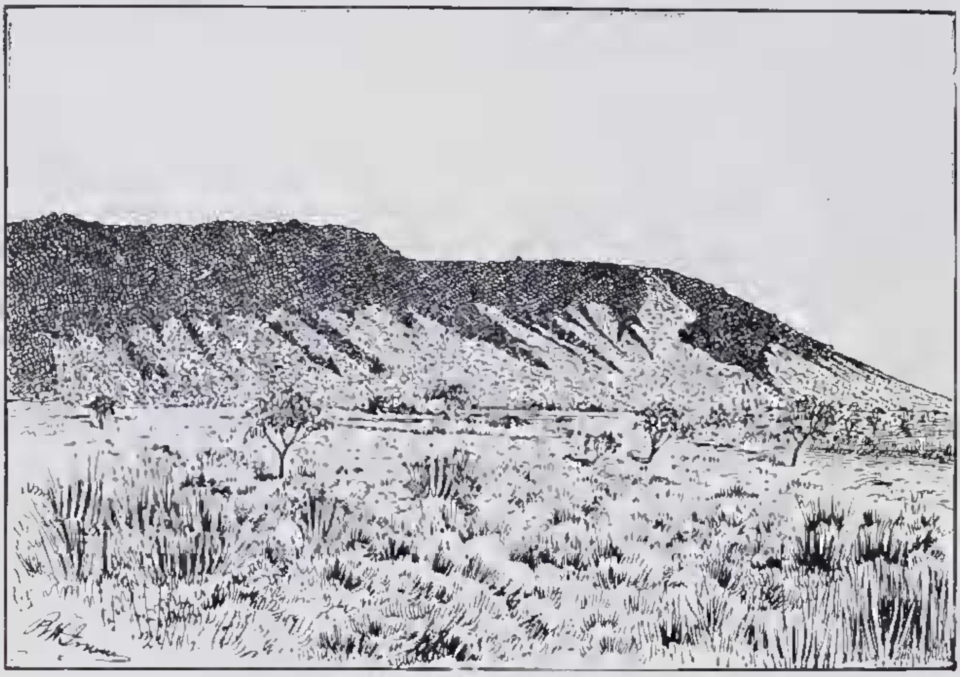

Fig. 28.
Dolerite Dyke, Black Range, Hillside, Pilbara Goldfield.

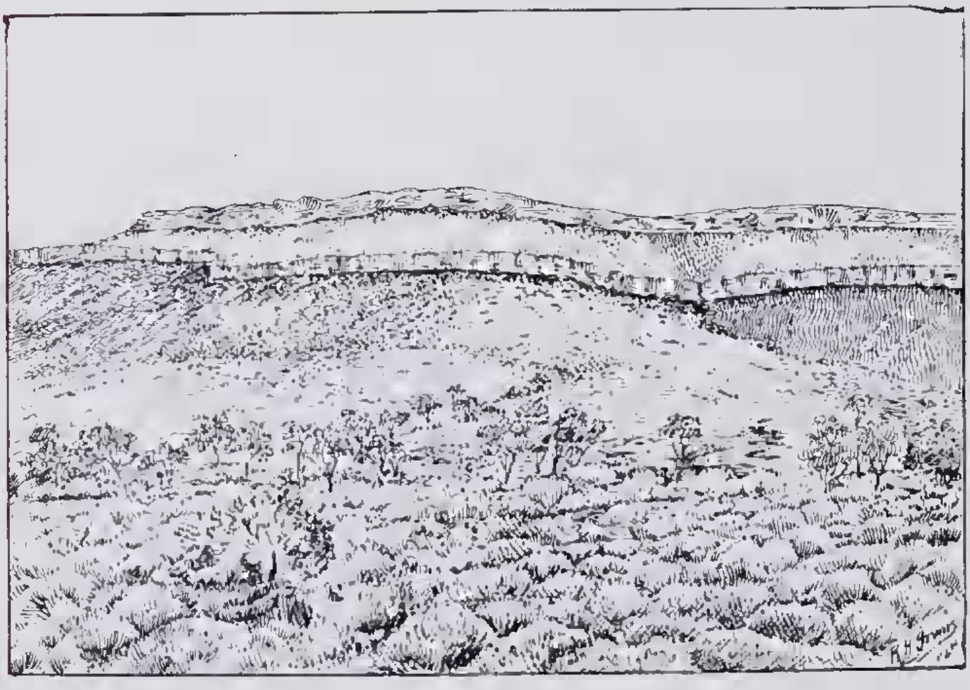

Fig 29.
Dolerite Sill in Sedimentary Rocks, Mount Frew.

*Lands Dept. Litho, 90/300.

A conspicuous hill in the watershed of Monkey Creek**, shows a beautiful example of a dolerite sill resting on indurated shales, with the cover overlying the dolerite removed by denudation. Occasionally an effect of the igneous intrusion in arching up the overlying strata may be noticed, an excellent instance of which is to be seen in Fig. 31) here the intrusion is laccolitic in character,

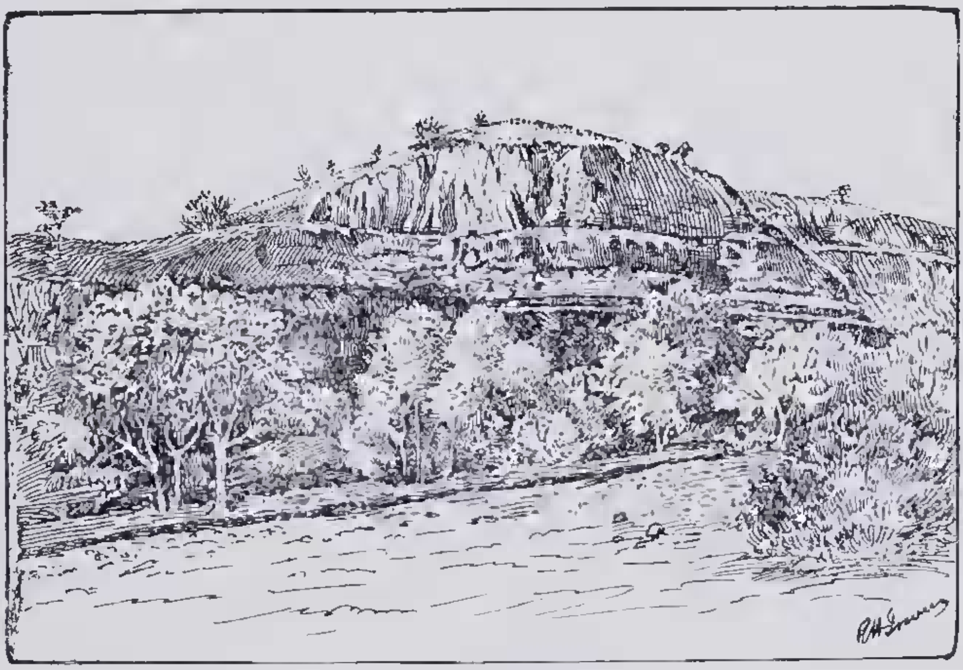

Fig. 30.
Quartz Dolerite Sill, resting on Shales, Monkey Creek.

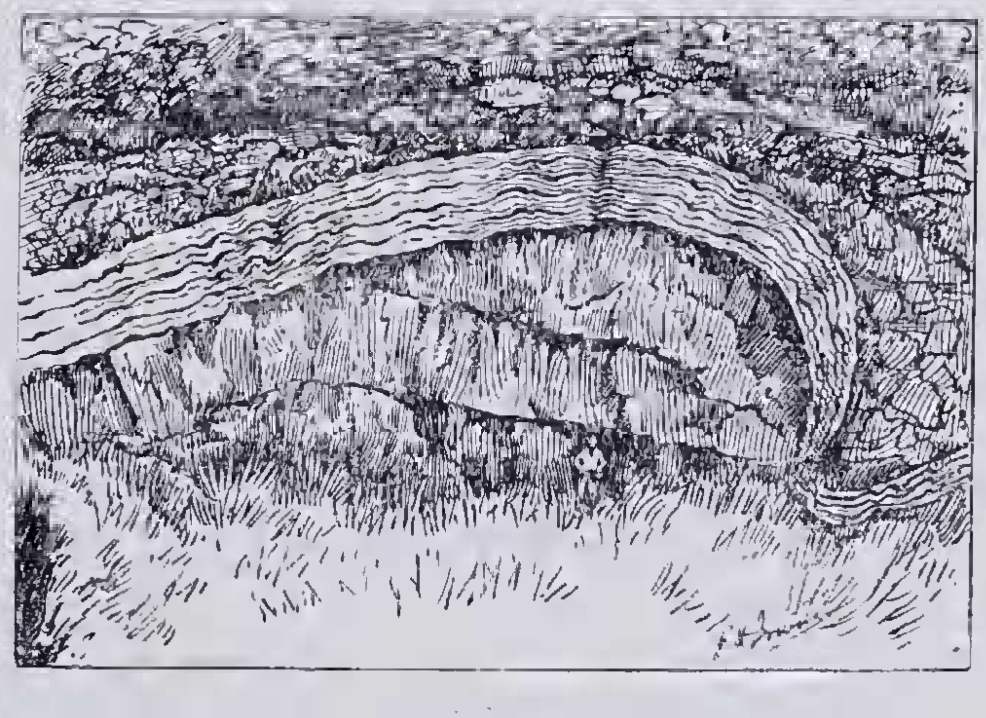

Fig. 31.
Sill in Sedimentary Rocks.

** Lands Dept. Litho. 80/300.

Near Kunningina Hill†, is to be seen a portion of what may be called a compound laccolitic form of intrusion of what is usually described as the cedar-tree type (Fig. 32) here tapering sheets of dolerite may be seen running out into the neighbouring sediments. the sedimentary rock being, as may be seen dipping away from the dolerite in all directions.

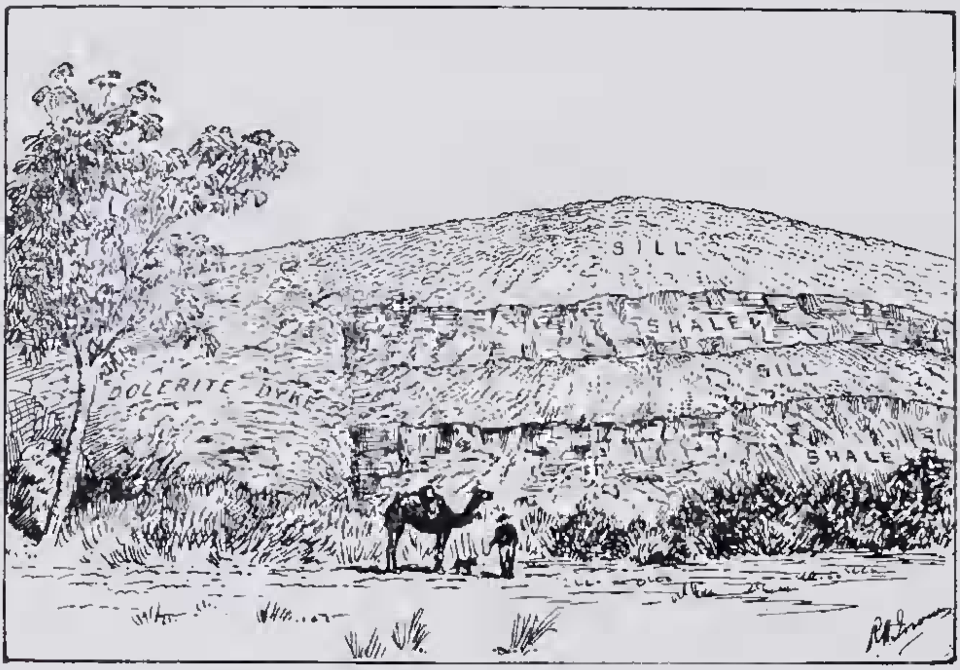

Fig. 32.
Laccolitic Intrusion, Cedar-Tree Type, Kunningina Hill.

Fig. 33.
Dolerite Dyke Cutting through Reef, Oroya-Black Range Mine, East Murchison Goldfield.

† Lands Dept. Litho. 99/300.

On the northern face of the plateau in the watershed of the Maitland River in the West Pilbara Goldfield, may be seen a splendid example of one of these dolerite dykes, cutting the horizontal strata transversely, but unfortunately no opportunity of photographing it could be had.

These dolerite dykes have been noticed in mine workings, traversing the auriferous deposits. An excellent instance of which may be seen in the workings in the Oroya-Black Range Mine at Sandstane. (Fig. 33). The dykes may also be seen at other localities outside the limits occupied by the Nullagine Beds, as at the Croydon Road Crossing on the Sherlock River. (Fig. 34).

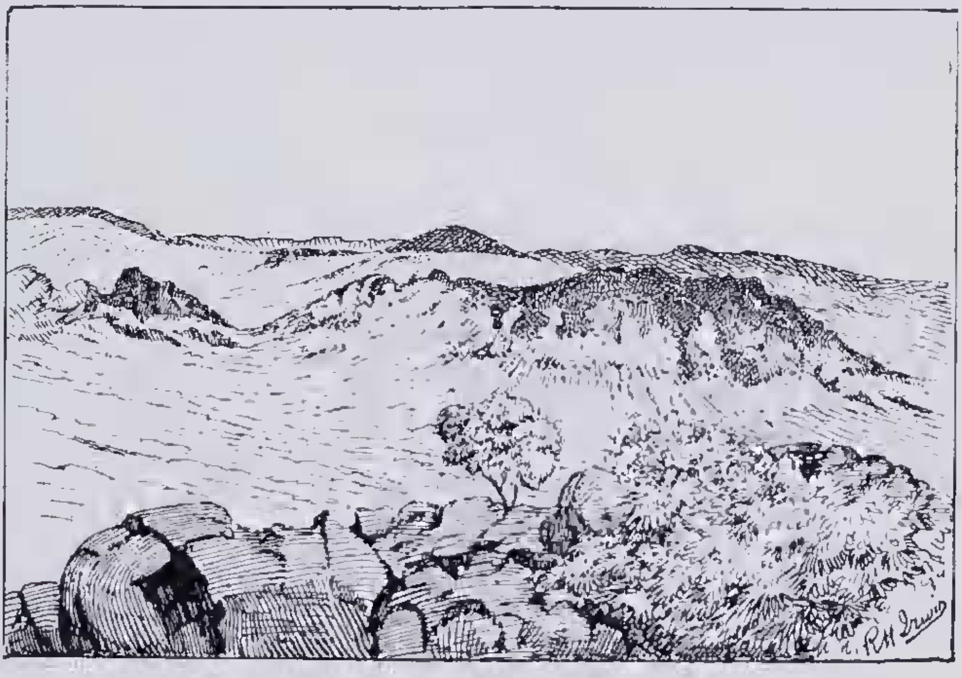

Fig. 34.

Gabbro Dyke, near Croydon Road Crossing, Sherlock River, West Pilbara Goldfield.

In addition to these dykes and sills, there are a large number of quartz reefs, containing more or less gold and copper traversing the Nullagine Formation, only however, in those special localities which have undergone more or less earth movement.

From such brief descriptions as it has been possible for me to give you during the short time at my disposal, it appears that during Nullagine Time, there must have been a huge reservoir of molten matter lying beneath the surface to the north of latitude 26, and merely awaiting a suitable opportunity of rising to the surface.

There is as yet little definite evidence as to the nature and composition of the parent magma, from which these igneous rocks were derived, nor any adequate explanation as to why the rocks were acidic in some localities and basic in others.

The geological age of these dolerite intrusions cannot, in the light of our present knowledge be fixed with any degree of certainty. As regards the problem connected with the relative age of the lavas, ashes, and the dykes and sills, there is but little direct evidence; it is possible that they may be grouped together into one series, which may be held to represent one distinct phase of the volcanic phenomena of the State.

Since their deposition the Nullagine beds have been uplifted, and are now disposed in a series of broad anticlinal folds, having taken part in orgraphic movements during a period which appears to have preceeded the formation of the Permo-Carboniferous strata. The beds were everywhere uplifted by mountain building processes accompanied by folding, faulting, and occasional plication. In the Strelley River gorge a section is to be seen which shows the sediments and associated volcanic rocks bent up into a sharp anticlinal fold, the axis of which is north-east and south-west. This fold is depicted in Fig. 35, but the fold was produced so long

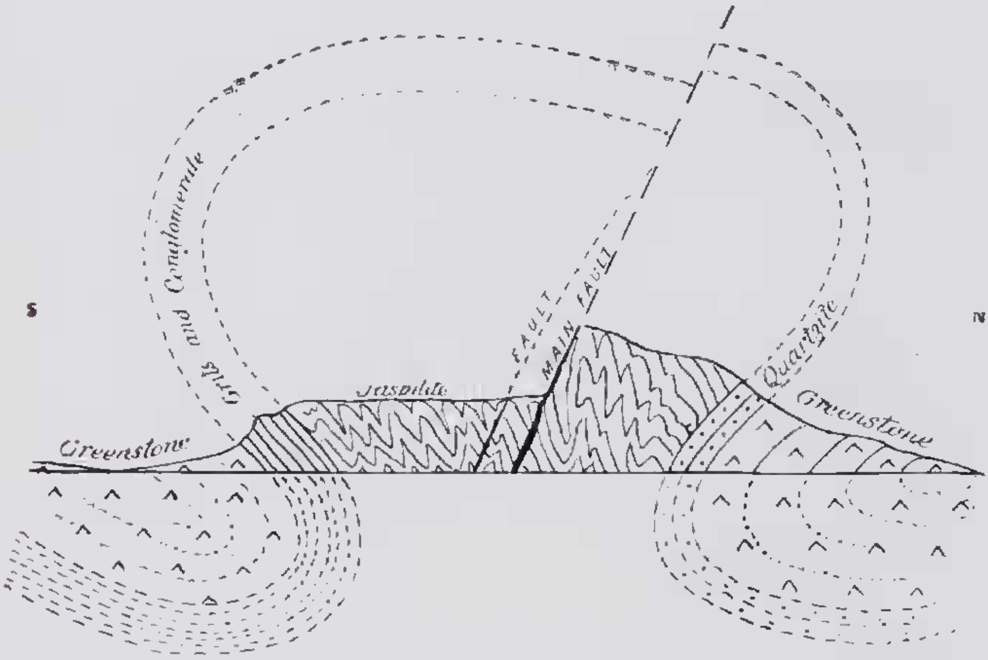

Fig. 35.
Generalised Section along the Strelley River Gorge, Kimberley Division.

ago that its crest has been worn away, and the arch snapped in two. The dotted lines represent the restoration of this arch. Another excellent example of this folding is to be seen in the denuded anticlinal at Bangemall, on the Lyons River, the two bands of quartzite which form the legs of the fold, rise as conspicuous serrated razor-backed ridges, traceable across country for many miles. (Fig. 36). This post-Nullagine movement was doubtless coincident with similar movements elsewhere in Australia, though at present these cannot be definitely correlated.

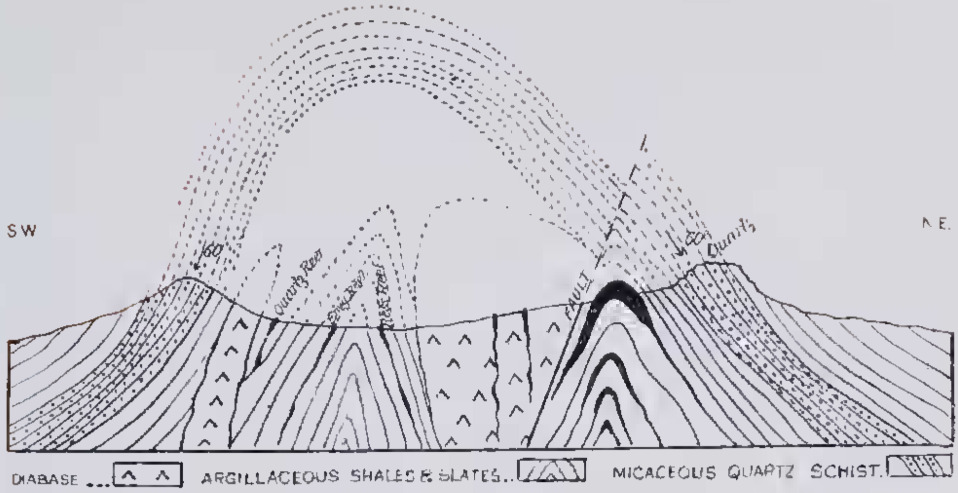

Fig. 36.
Generalised Section across the Bangemall Anticline, Gascoyne Goldfield.

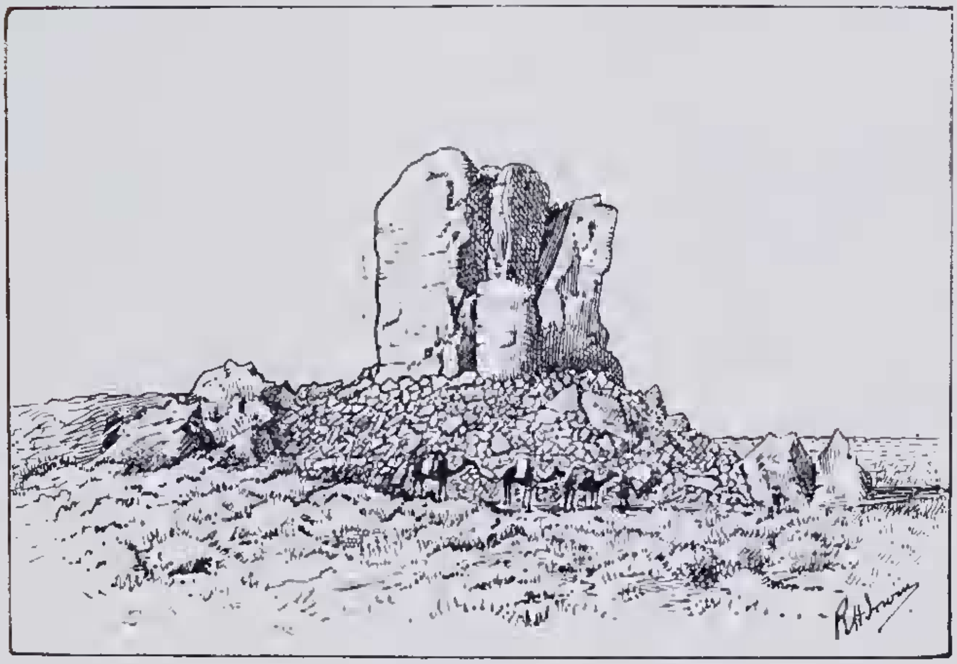

Fig. 37.
Sandstone Butte, thirty-three miles east of 692 M. Rabbit Proof Fence.

In post-Nullagine times erosion of the series was excessive, and possibly long continued. The strata were cut down until in some cases they were represented by mere isolated outliers (Fig. 37) such as may be seen thirty-three miles east of the 692 mile* post on the rabbit proof fence near the head of the Oakover River. The horizontal or gently inclined beds have been deeply incised, and narrow trenches cut into them, forming magnificent canons, but often some miles in length down which the waters find their way seawards. A view of one of these canons, carved out of the

* Lands Dept. Litho. 99/300.

quartzites of the Prince Regent River may be seen in Fig. 38). These sediments lie on a much lower geological horizon than the lava flows of Mount Hann. These canons are of great beauty, and it is much to be regretted circumstances have prevented many of them being photographed.

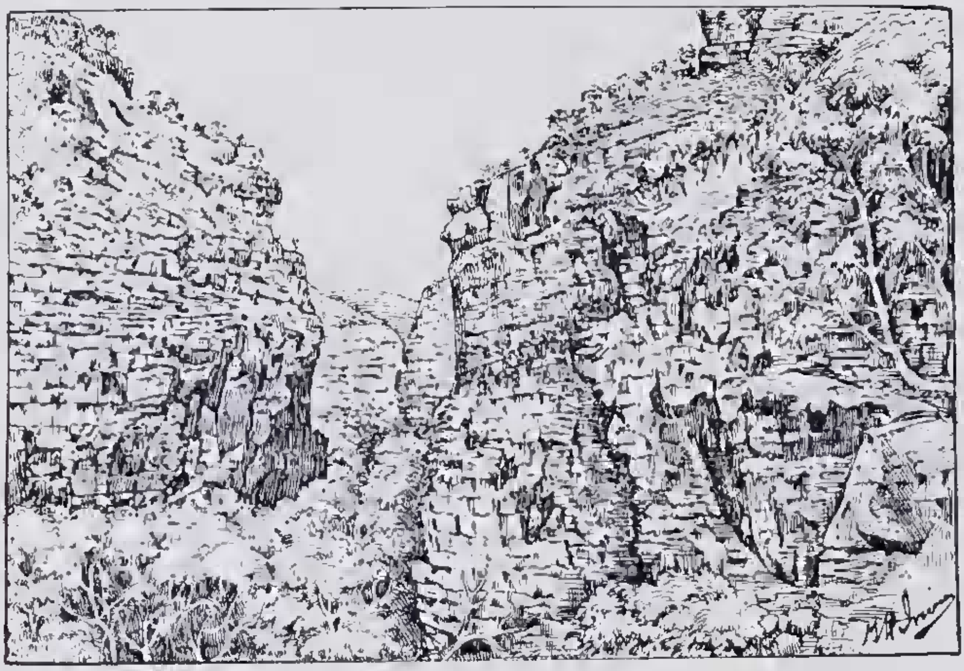

Fig. 38
Cañon, Prince Regent River, Kimberley Division.

For a very long period of time there was a danger of our geological observations being lost in a mass of detail, and the time is rapidly approaching when what may be called the histological aspect of the subject, can give place to generalisation.

The recognition of the positon of the Nullagine Formation in the geological time scale is a point of considerable importance. None of the beds, despite the fact that the dolomites are of marine origin, have as yet yielded any fossils, hence any correlation of the strata will be little else than tentative. The earliest observer, Mr. H. P. Woodward assigned a Devonian Age to the formation, though the evidence does not seem to be conclusive. The next observer, the late Mr. Becher, writes that of "the age and origin of these interesting Nullagine beds nothing definite is known." Prof. David infers that the beds are "probably of older Palaeozoic age (? Pre Cambrian.")

The only direct evidence we have bearing on the question of their age, is that acquired by my colleague, Mr. Talbot, in his recent explorations in the north. The beds of the Nullagine Formation are seen to pass unconformably beneath much newer strata in the Paterson and Broadhurst Ranges, in the watershed of the Rudall River.

These newer beds which occupy the whole of the country traversed by the ill-fated Calvert expedition, which extend as far north as the Fitzroy River Valley. Fossiliferous Mesozoic rocks have been met with in this area at a depth of about 1,400 feet in one of the bores put down in the search for artesian water at Derby. There is, therefore, no positive evidence as to the age of the Nullagines beyond the Pre-Cambrian or Archaean below, and the Mesozoic above, the latter limit being determined by the *Belemnites* in the bore-hole referred to.

Geologists are unfortunately, somewhat prone to refer every stratigraphical or lithological unit to European or other standards, and to give names to the beds of which they are supposed to be the equivalent. I am afraid that any attempt at present to harmonise the time-tables, will only end in confusion, and tend rather to hinder than to advance knowledge.

In its lithological characters, its structural relationships, and its igneous phenomena, the Nullagine Formation bears a very marked resemblance to the beds in South Africa known as the Potchefstroom or Transvaal System, of the age of which all that it is possible to say that it is Pre-Devonian. The Nullagine beds also bear a very close relationship to the Bijawar or Cuddapah Series of Peninsular India, which constitute a part of the Purana Group, which is assumed to be the equivalent of the Algonkian as the term was originally understood in American stratigraphical nomenclature.

The seat of all the Western Australian mineral wealth lies in the rocks more or less directly associated with the beds of the Nullagine Formation, and one at any rate of the unsolved problems which presents itself, is, the ore deposition associated with Pre-Nullagine time, or is it more recent than the mountain building era, during which the schistose structure was developed?

In the multiplicity of the problems, the master one is that just propounded, and the solution of it involves pretty well all others, a condition which almost instinctively brings to mind the words in the Talmud:—

"The day is short, and the work is great, it is not incumbent upon thee to complete the work, but thou must not therefore cease from it."

We are glad to see, that despite all the difficulties, geological science, which is perhaps one of the very best of grounds for training the faculty of observation, and the power of reasoning, has taken its rightful place in the highest educational institution in Western Australia. In years to come, we shall look forward to the time, when some of those trained within its walls will play a part in helping to solve some of the many problems in Western Australian geology, of some of which but a passing glimpse has just been afforded you.

"Wherever and by whatever means sound learning and useful knowledge are advanced, there to us are friends. Whoever is privileged to step beyond his fellows on the road to scientific discovery will receive our applause and if need be our help. Welcoming and joining in the labour of all, we shall keep our place amongst those who clear the roads and remove the obstacles from the path of science, and whatever be our own success in the rich fields which lie before us, however little we may now know, we shall prove that in this our day we knew at least the value of knowledge, and joined heart and hands in the endeavour to promote it."

So spoke the President of the British Association for the Advancement of Science in the year 1865, and to his words I merely add by way of an echo, "So say all of us."

My self-imposed task is over; my term of office as your President, has now come to an end, and in vacating the Chair, in favour of my successor, may I ask you to ponder over the deeper meaning conveyed in the words of one, alas! of our very few, Australian poets:—

"God said let there be light. They but fulfil
With banded aim, His first recorded will,
Who pass obedient to the prime command,
The torch of Science on from hand to hand."